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January 18, 2000

HAND DELIVERED
Ms. Magalie R. Salas, Secretary
Federal Communications Commission
445 12th Street SW
Room TW-B204
Washington DC 20554

Re: ET Docket No. 99-231, Amendment of Part 15 of the Commission's Rules Regarding Spread Spectrum Devices — *Ex Parte Filing*

RESPONSE OF THE WIRELESS ETHERNET COMPATIBILITY ALLIANCE TO THE REPLY COMMENTS OF THE COMMITTEE FOR UNLICENSED BROADBAND ENABLEMENT

Dear Ms. Salas:

The Wireless Ethernet Compatibility Alliance (WECA) responds to the Reply Comments of the Committee for Unlicensed Broadband Enablement filed Nov. 19, 1999 (CUBE Reply Comments). WECA is an association of product vendors and service providers that certifies products for interoperability with the IEEE 802.11 spread spectrum wireless LAN standard.

WECA opposes a proposal put forward by the Home RF Working Group (Home RF), and supported by CUBE, to authorize wideband frequency hopping systems.[1] The attached Technical Statement provides details and supporting analysis for WECA's rebuttal of the CUBE Reply Comments.

[1] Amendment of Part 15 of the Commission's Rules Regarding Spread Spectrum Devices, 14 FCC Rcd 13046 (1999) (Notice of Proposed Rule Making).

This letter is expressly endorsed and supported by the following entities:

3Com Corporation
Aironet Wireless Communications, Inc.
Alantro Communications, Inc.
Apple Computer, Inc.
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A. Introduction

This proceeding turns on two questions:

1. Would the proposed wideband frequency hopping transmitters cause excessive interference to conventional spread spectrum receivers that operate in compliance with the present rules?

2. If the answer to (1) is yes, would wideband frequency hopping equipment bring sufficient additional benefits to the public to justify the disruption to existing equipment?

The filings of WECA and several others have shown that the answer to the first question is yes. Interference from wideband frequency hoppers would be far worse than from conventional spread spectrum equipment, and would greatly reduce the number of transmitters that can operate in a given area. The wideband proposal directly threatens the continued use of spread spectrum equipment sold and installed by WECA members worth $1 billion. (Inclusion of non-WECA-members would bring the total to approximately $1.3 billion.) CUBE'S Reply Comments not only fail to alleviate these concerns, but support them.

The record also establishes that the answer to the second question is no. Wideband frequency hoppers cannot achieve the throughput their proponents claim, in practice and at reasonable cost. If the technology caused no untoward interference, its unworkability would have no regulatory significance, and the Commission could simply let it fail in the marketplace. But because wideband frequency hoppers threaten compliant equipment, the Commission must consider whether the benefits they offer justify the risks. The record shows they do not — and, again, the CUBE Reply Comments offer no convincing data to the contrary.

B. CUBE's Public Interest Arguments are Inapposite.

CUBE devotes large parts of its pleading to arguing the public interest in the Home RF proposal.[2] These issues are not in dispute. Specifically, WECA has no quarrel with the proposition that Home RF products would be in the public interest ***if*** they could achieve their claimed data rates without unreasonable interference to present equipment, at competitive cost. The question is not whether these are desirable objectives, but whether they can be achieved. The record shows these objectives are impracticable.

C. CUBE Has Failed to Resolve Concerns about Interference from Wideband Frequency Hoppers to Existing Spread Spectrum Devices.

As noted, the primary issue before the Commission is whether wideband frequency hoppers will interfere unduly with existing spread spectrum systems.

Power levels. CUBE continues to assert that wideband frequency hoppers will not cause worse interference than existing equipment. Its analysis relies primarily on a proposed reduction of maximum power for 3 and 5 MHz frequency hoppers, from 1 watt to 320 or 200 mW, respectively.[3] WECA, on the other hand, has explained that modern wireless LAN systems and portable data terminals operate at far lower powers, typically about 30 mW, and that nearly all Bluetooth radios will employ only about 1 mW.[4] End users prefer low operating power because it lengthens battery life and increases frequency re-use. Home RF equipment, in contrast, will

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[2] CUBE Reply Comments at 9-15, 42-45.

[3] CUBE Reply Comments at 26-29.

[4] WECA Comments at 6 (filed Oct. 4, 1999).

have to operate at or near its maximum power even over short ranges.[5] To benefit from wideband equipment's proposed "reduction" to 320 or 200 mW, conventional equipment would have increase its power levels by at least 10 dB. That would harm both individual users and the public interest.

CUBE, in response, "cannot agree completely" that most wireless LANs operate at power levels well below one watt.[6] Its evidence to the contrary consists only of one data point, that the vast majority of Proxim OpenAir products "leave the factory" in a nominal 500 mW configuration, together with unsupported speculation based on the web sites of two other manufacturers.[7] The attached Technical Statement shows that Proxim OpenAir radios often must operate at relatively high power simply because they can't function otherwise.[8] OpenAir radios have a shorter range than direct sequence radios operating at one-tenth the power! — hardly an efficient precedent for band-sharing policy.

In any event, CUBE has its basic facts wrong. The majority of direct sequence wireless LAN products manufactured by WECA member companies operate at 20 to 30 mW transmit power. WECA does not know of ***any*** direct sequence radio sold for indoor use that transmits in

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[5] WECA Comments at 7. For example, WECA has shown that a wideband frequency hopper at 10 Mbps using 4FSK modulation would require 12 dB higher transmitted power than a comparable direct sequence system using DQPSK modulation. WECA Reply Comments at 6 (filed Nov. 19, 1999).

[6] CUBE Reply Comments at 29.

[7] CUBE Reply Comments at 29-30. Proxim is a CUBE member. CUBE adds that Proxim sells more than 50% of all 2.4 GHz wireless LANs, *id.*, but does not say what fraction of those are OpenAir radios, or what power levels other Proxim products may use. Even CUBE's carefully worded statements on its own member's products do not unambiguously support its position.

[8] Technical Statement at ¶ 2.6.2.

excess of 100 mW.[9] All of the existing systems will be extremely vulnerable to interference from wideband frequency hoppers that outpower them by 8 to 10 dB.

Hopping rates. WECA objects to mandating higher hopping rates for wideband systems, and has shown that faster hops would lead to increased interference.[10] While continuing to argue the point, CUBE nonetheless is willing to drop that requirement in favor of keeping higher hopping rates optional, as under the present rules.[11] WECA insists that higher hopping rates are wholly ineffective, and indeed are counterproductive, as an interference-reduction measure, and agrees that the rules on hopping rates should be left unchanged.[12]

Overlapping channels. WECA has shown that Home RF's proposed use of overlapping frequency hopping channels would cause undue interference in the band.[13] Indeed, both European and U.S. regulations prohibit the use of overlapping channels. CUBE disputes WECA's arguments on this point, yet neither CUBE nor Home RF has presented any test data on the susceptibility of wideband frequency hoppers to interference from the overlapping channels of other wideband hoppers. Such interference would have an immediate impact on nearby conventional systems, because frequent retransmission of lost packets would multiply a wideband system's occupancy in the band and hence add further to interference.

In principle, Home RF could achieve wideband operation on channels that do not overlap, if it hopped on fewer frequencies. For example, the 2400-2483.5 MHz band could accommodate 20 non-overlapping 4 MHz channels. But the Commission foreclosed this option in 1996, when it rejected a request by Symbol Technologies, Inc. to reduce the minimum number of hopping channels from 75 to 20, under reduced power. The Commission said:

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[9] The only direct sequence radios configured for higher power are used for fixed building-to-building applications. These typically must cover distances ranging up to tens of kilometers, and hence produce very low signal levels at the receiver. They would likewise be vulnerable even to reduced-power wideband frequency hoppers. *See* WECA Comments at 7.

[10] WECA Comments at 6.

[11] CUBE Reply Comments at 32.

[12] Technical Statement at ¶ ¶ 2.6.4-2.6.5.

[13] WECA Comments at 5.

> We have serious concerns that implementing Symbol's requested changes could result in severe increases in the potential for harmful interference, both to the authorized radio services and to other Part 15 devices operating in these bands. Symbol's request to decrease the number of hopping channels would result in an increase in the average time during which the channels are occupied by a spread spectrum transmission. In addition, Symbol's request to increase the bandwidth of the hopping channels would broaden the spectrum over which interference from the frequency hopping systems could be received. Thus, we believe that implementing these changes would be detrimental to other narrowband and wideband systems operating in these bands.[14]

All of the factors cited here by the Commission as increasing interference from fewer but wider hops apply equally — or more so — to the Home RF proposal.

Channel occupancy. WECA argues that a frequency hopping system with channels 3 MHz or 5 MHz wide would occupy any given frequency three times or five times more, on average, than a 1 MHz system does.[15] The threat of interference to both frequency hopping and direct sequence systems would increase accordingly. CUBE find this analysis to be "completely false."[16] Rather, CUBE says, a wideband frequency hopper would occupy multiple 1 MHz slices of spectrum no more than a 1 MHz frequency hopper does, in the worst case, and much ***less*** in the center 1 MHz channel.[17] But CUBE's own test data shows the opposite. A 5 MHz frequency hopper presents 4 dB more interference to an existing frequency hopping system in the center channel than a compliant 1 MHz frequency hopper does. The difference rises to 16-23 dB more interference at ±2 MHz from the center frequency. At ±3 MHz, the wideband hopper presents 20 dB more interference.[18]

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[14] Amendment of Parts 2 and 15 of the Commission's Rules Regarding Spread Spectrum Transmitters, 11 FCC Rcd 3068, 3072 at ¶ 23 (1996) (footnote omitted).

[15] WECA Comments at 5.

[16] CUBE Reply Comments at 28.

[17] CUBE Reply Comments at 28.

[18] Technical Statement at ¶ 2.6.1.

Intersil Corporation and others have filed technical studies that show increased interference from wideband frequency hoppers into conventional frequency hopping and direct sequence systems.[19] Supporting these findings is a more recent submission by Silicon Wave, Inc., a member of both the Bluetooth Special Interest Group and the Home RF Working Group. Contrary to CUBE's assertions, Silicon Wave, Inc. shows that the proposed power reductions for wideband frequency hopping systems are entirely inadequate to prevent undue interference to existing systems.[20]

Finally, CUBE insists that a direct sequence system can legally put out more power across a 5 MHz bandwidth than a proposed Home RF transmitter could.[21] Again, however, a comparison of Home RF and conventional systems operating at their respective maximum powers is irrelevant, because the large majority of conventional systems operate at far lower powers.

D. CUBE Has Failed to Establish That Wideband Frequency Hoppers Can Achieve Their Promised Performance.

WECA has shown that a wideband frequency hopper is highly susceptible to multipath distortion caused by reflections from building walls and other surfaces. To operate reliably indoors, the system will have to resend packets, which will degrade the system to the slower data

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[19] Jim Zyren, *Analysis of WBFH Power Reduction and Increased Hop Rate on Other Users of the 2.45 GHz ISM Band,* attachment to Letter from James T. Carlo *et al.*, IEEE, to Magalie R. Salas, Secretary, FCC (electronic filing Oct. 2, 1999); Jim Zyren & Pierre Gandolfo, *Simulation of WBFH Multipath Performance* (Intersil Corp., electronic filing Oct. 4, 1999); Donald C. Johnson, *Interference Potential of Wide-Band Frequency Hopping Systems on Packet Data Systems*, attachment to Letter from James T. Carlo *et al.*, IEEE, to Magalie R. Salas, Secretary, FCC (electronic filing Oct. 2, 1999); Jim Zyren & Pierre Gandolfo, *Effects of WBFH Interference on Bluetooth Receiver Reliability* (Intersil Corp., electronic filing Sept. 29, 1999); J. Zyren, *Analysis and Simulation of Overlapped Frequency Hopping Channels*, attachment to Comments of Intersil Corporation (filed Aug. 30, 1999); Letter from James T. Carlo *et al.*, IEEE, to Magalie R. Salas, Secretary, FCC (filed Aug. 19, 1999).

[20] Ex parte Statement of Silicon Wave, Inc. (dated Dec. 17, 1999; date-stamped Dec. 28, 1999).

[21] CUBE Reply Comments at 28-29.

rates typical of conventional systems. The wideband properties of the system convey no advantage to offset the greatly increased interference potential.[22] Worse, the high incidence of packet retransmissions translates directly to a higher incidence of interference into other systems.

CUBE counters that the duration of the multipath delays will be smaller than those estimated by WECA and others, and hence less disruptive.[23] WECA estimates delays of 20-40 nanoseconds in a typical residential setting, increasing in larger homes,[24] while CUBE predicts only a 10 ns delay spread in a typical residence.[25] But CUBE has mis-cited its authorities.[26] Delay spread values for almost half the homes in the United States are large enough to cause significant interference between direct and reflected signals.[27] CUBE alleges that it can correct for 40-50 ns of multipath delay at a cost of 1/4 cent per unit,[28] but has made no effort to substantiate the statement. Until it does, the Commission should disregard the allegation. In any event, nothing in the proposed rules would restrict wideband frequency hoppers to residential environments. CUBE concedes that the delay spread in most office environments reaches 40-70 ns,[29] yet offers no hint of how a wideband frequency hopper can be expected to operate in the presence of such delays.

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[22] WECA Comments at 9-10.

[23] CUBE Reply Comments at 17.

[24] WECA Comments at 10.

[25] CUBE Reply Comments at 17.

[26] CUBE Reply Comments at 17, n.44, *citing* van Nee, *Delay Spread Requirements for WLANs in the 2.4 GHz and 5 GHz Bands*, Document IEEE P802.11-97/125 (Nov. 1999).

[27] Joint Technical Committee of Committee T1 R1P1.4 and TIA TR46.3.3/TR45.4.4 on Wirelsss Access, *Draft Final Report on RF Channel Characterization*, Paper No. JTC(AIR)/94.01.17-238R4 (Jan. 17, 1994). In a home with plasterboard internal walls and a brick or masonry exterior, for example, the multipath reflections are due to scattering off the external walls, not the internal walls, increasing the value of the delay spread.

[28] CUBE Reply Comments at 17-18.

[29] CUBE Reply Comments at 17.

The effects of multipath interference aside, wideband frequency hopping radios that employ a 4-level FSK modulation scheme and are capable of reliably delivering the promised data rates will be extremely inefficient, and will require high transmit powers to operate even over very short ranges. Further, such radios will be difficult, if not impossible, to build cost-effectively. Finally, the record shows that the wideband proponents have provided no data whatsoever to support their claimed maximum data rates of 6 Mbps in a 3 MHz channel and 10 Mbps in a 5 MHz channel.

Conclusion

The Commission's spread spectrum rules are an unparalleled success. Millions of spread spectrum devices provide reliable, inexpensive communications services. They promote efficiency and drive down costs in every sector of the economy, and bring convenience to millions of consumer households. Their numbers will increase several times over with the introduction of Bluetooth transmitters, soon to become ubiquitous in computers, wireless phones, and dozens of other products.

By limiting spread spectrum operation to modulation schemes that present a low threat of interference, the Commission's Rules have enabled vast numbers of these devices to function together in a small amount of spectrum. The hospitable RF environment encourages all users to get by with minimum power, which maximizes efficient frequency re-use.

The Home RF proposal threatens to destabilize this success. Wideband frequency hoppers would cause more interference at any power than existing systems do. Worse, their inherent inefficiency would require them to operate routinely at or near the maximum permitted power, making it impossible for existing low-power systems to function nearby, and their susceptibility to multipath distortion will necessitate the frequent retransmission of packets, driving up channel occupancy and hence interference. The inevitable outcome will be an "arms race" in output power as systems compete to push signals through an increasingly noisy environment.

The public interest cannot sanction this harm unless the likely benefits are so great as to outweigh the damage. But that is not the case here. To the contrary, wideband frequency hoppers operating in realistic environments cannot provide significant improvement in performance over existing systems.

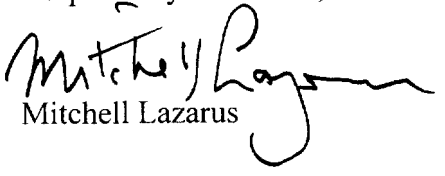
The Commission should reject the Home RF proposal. The risks it poses far outweigh any likely benefits.

■ ■ ■ ■

I am filing the original and one copy of this written ex parte communication pursuant to Section 1.1206(a)(1) of the Commission's Rules.

Kindly date-stamp and return the extra copy of this letter. If there are any questions about this letter, please call me at the number above.

Respectfully submitted,



Mitchell Lazarus

ML:deb

Enclosure

cc (by hand):
Chairman William E. Kennard
Commissioner Michael Powell
Commissioner Gloria Tristani
Commissioner Harold Furchtgott-Roth
Commissioner Susan Ness
Dale Hatfield
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cc (by mail):
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Attorneys for the Committee for Unlicensed Broadband Enablement (CUBE)

TECHNICAL STATEMENT

Reply Comments

of the

Wireless Ethernet Compatibility Alliance

In ET Docket 99-231

With the Express Support of:

3Com Corporation
Aironet Wireless Communications, Inc.
Alantro Communications, Inc.
Apple Computer, Inc.
Cisco Systems, Inc.
Dell Computer Corporation
Intermec Technologies
Intersil Corporation
Lucent Technologies, Inc.
No Wires Needed, Inc.
Nokia, Inc.
Samsung Electro-Mechanics Co. LTD
ShareWave, Inc.
Symbol Technologies, Inc.
Wayport, Inc.
Zoom Telephonics, Inc.

Jim Zyren
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Table of Contents

1.0 Executive Summary

WECA has carefully analyzed the reply comments of the Committee for Unlicensed Broadband Enablement (CUBE). This document is a point-by-point rebuttal, and is intended to provide the Commission with a ready means of assessing the many inaccuracies in the CUBE filing.

Notwithstanding CUBE's criticisms, WECA retains full confidence in its earlier findings:

1.) The proposed power reductions for WBFH are entirely inadequate to prevent increased interference to other users.

2.) Raising the hop rate for WBFH systems will increase interference to other users.

3.) The use of overlapping channels will result in more frequent and more severe collisions among WBFH systems, and hence more interference to other users.

4.) The proposed WBFH systems are incapable of delivering the benefits to consumers claimed by proponents. Specifically, WBFH systems will be unable to deliver 6 Mbps in the 3 MHz channel or 10 Mbps in the 5 MHz channel.

As demonstrated below, CUBE's claims that the proposed reductions in power will protect other users are based in part on a misinterpretation of its own analysis. Further, the proposed power reductions are inconsistent with the Commission's previous ruling in the 902-928 MHz ISM band [2]. In that proceeding, the Commission ruled that power reductions should be proportional to the square of the reduction in the number of *non-overlapping* channels. As the Intersil analysis showed [3], the number of overlapping channels is largely irrelevant. Collision rates among FHSS systems are dependent on the number of orthogonal (non-overlapping) channels.

The record also shows that higher mandatory hop rates for WBFH systems will result in increased interference in the spectrum, regardless of the applications or modulation methods employed by victim users. The exact magnitude of the increased level of interference to other

users depends on many factors. Although the increase in hop rate was originally represented to the Commission as an interference reduction measure, its actual effect would be exactly the opposite.

In assessing the potential interference effects of WBFH on existing DSSS systems, the Commission stated: "[I]t appears that the proposed reduction in output power and time of occupancy would offset any potential increase in interference." NPRM at para. 9. The Commission clearly had been led to believe that increasing the hop rate would mitigate interference to other users. However, CUBE now indicates that the recommended increase in hop rate was intended to reduce latency in TDMA voice applications.

WECA remains opposed to any *mandatory* increase in hop rates. WECA does not oppose the use of higher hop rates for FHSS systems at the discretion of the manufacturer, consistent with the Commission's current rules. However, under no circumstances can increasing the hop rate be shown to reduce interference to other users. WECA therefore applauds CUBE's decision to support leaving the minimum hop rate unchanged.

CUBE has gone to some length to refute the Intersil analysis of the effects of overlapping channels [1]. As described more fully below, CUBE's criticisms are without merit. Most of its comments are demonstrably inaccurate and stem from a failure to thoroughly review the Intersil analysis. Intersil's results have now been independently confirmed by the findings of Silicon Wavein this proceeding. WECA affirms its confidence in the accuracy of the analysis it has submitted to the Commission. The use of overlapping channels for WBFH systems will result in more frequent and more severe collisions among users of such systems, whose frequent need to retransmit lost packets will increase interference to other users as well.

None of CUBE's testing provides any data whatsoever in which WBFH receivers were the target systems. Such tests would have clearly demonstrated the accuracy of the findings presented to the Commission in the Intersil analysis on the use of overlapping FHSS channels [1]. Significantly, prohibiting the use of overlapping channels could reduce collisions among WBFH systems by up to 50%.

Finally, proponents have completely failed to demonstrate that WBFH systems can deliver the promised data rates of 6 Mbps in a 3 MHz channel, or 10 Mbps in a 5 MHz channel.

After more than one year and hundreds of pages of submissions to the Commission, the proponents still have not offered the slightest credible evidence that these data rates are in fact feasible for the systems they describe. In particular, the simulations submitted to the Commission by the HomeRF Technical Committee are based entirely on 2FSK systems, which would have a raw data rate of only one half of the claimed data rates.

The latest CUBE submission is similarly devoid of any substantive data that would lend credence to the claimed data rates. Unless those claims can be effectively substantiated, proponents will be unable to demonstrate that WBFH can serve applications such as streaming video and CD quality audio. The underlying reasons for the dearth of technical data in this point are in fact the inherent unreliability of such systems. Although HomeRF claimed that such data rates could be achieved via the use of "the same trivial FSK modulation formats" [4] as are currently in use, they have consistently and completely failed to deliver any evidence that such systems are, in fact, practically realizable.

The Commission must base its decision on facts supported by the record. But many of the points CUBE presents as established facts are merely unsupported claims. Many of CUBE's criticisms of its opponents' technical analyses show CUBE's incomplete understanding of the material it criticizes. Still other comments by CUBE are simply the result of mistakes.

2.0 WECA Rebuttal of the Comments by CUBE

To assist the Commission in reaching a technically defensible result, the following pages identify and respond to the major misrepresentations and errors in CUBE's filing. The WECA response immediately follows each cited CUBE comment. To facilitate reference, WECA rebuttal statements are organized under the same outline as the CUBE document.

2.1 CUBE Summary Statement

2.1.1 WBFH Cannot Deliver Claimed Data Rate and Performance

CUBE Reply Comments, page ii:

"Moreover, the Commission should not be lulled into believing that any other wired or wireless technology can achieve the benefits of WBFH. No existing wired or wireless technology

– including existing FH and DS systems, as well as other unlicensed systems – can provide the bandwidth, price and performance capabilities that WBFH offers."

Response:

Proponents of WBFH have consistently made claims of regarding lower prices and better performance. Yet the record in this proceeding indicates that these claims remain completely unsupported by credible technical data. CUBE and others assert that WBFH systems will be capable of spectral efficiencies of 2 bits/sec/Hz, which are required to provide 6 Mbps in a 3 MHz channel or 10 Mbps in a 5 MHz channel. However, supporting technical material presented to the Commission in this proceeding is based almost exclusively on analysis of 2-level Frequency Shift Keyed (2FSK) systems which deliver only half of the promised data rates. Even at these lower data rates, WBFH systems will require far more transmit power to provide reliable data delivery (as measured by BER) compared to DSSS systems which employ Phase Shift Keyed (PSK) modulation, as demonstrated by the Eb/No curves shown in Figure 2.1.1-1.

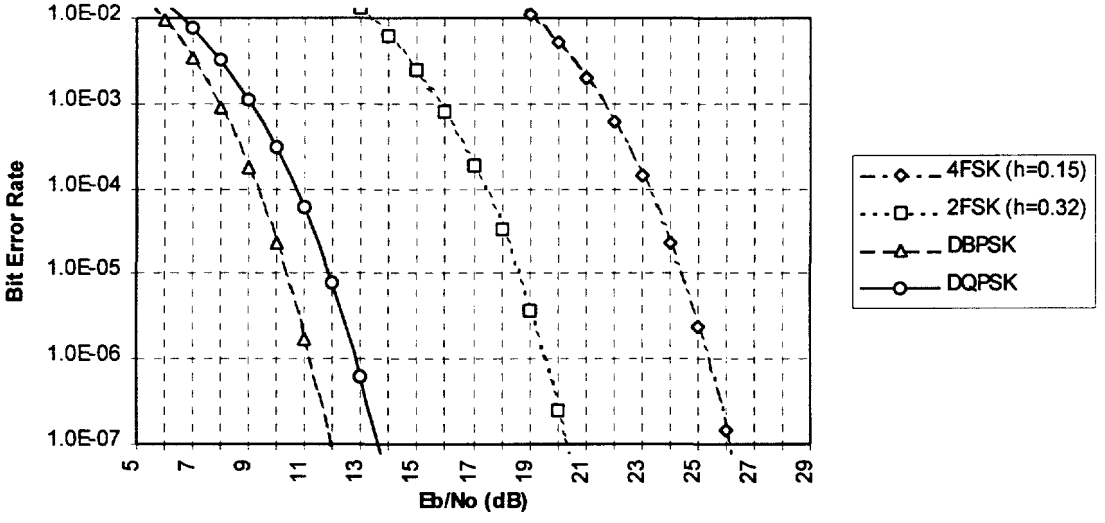

Figure 2.1.1-1 Eb/No vs. BER for FSK and PSK Waveforms

Until some credible evidence can be presented which demonstrates how WBFH systems which employ "the same trivial modulation formats" [4] as systems which are currently in use, claims of lower cost should be regarded with suspicion. It is easy to build a cheap radio. It is far more difficult to build a low cost radio which is capable of reliably delivering the data rates

claimed by the proponents of WBFH. Radios which are sold based on over-inflated claims will, in fact, do a disservice to consumers regardless of the selling price.

2.2 CUBE Background Statement

2.2.1 No Evidence to Support Claimed Data Rates

CUBE Reply Comments, page 4:

"In particular, WBFH devices will enable FH spread spectrum technologies to achieve data rates of 10 Mbps and, thereby, meet end users' needs for high bandwidth transmissions and remain competitive with other wired and wireless technologies."

Response:

As mentioned above, the analysis of the HomeRF Working Group presented to the Office of Engineering and Technology (OET) on February 25, 1999 was based completely on the 2FSK waveform, which will deliver only one half of the promised data rate. Even so, as will be described more fully below, that analysis rested on seriously flawed assumptions and grossly overstated the reliability of WBFH systems.

The only other submission in this proceeding which makes a serious attempt to provide the technical rationale in support of WBFH are the comments of CUBE itself. Even there, however, no data has been presented to substantiate that WBFH systems are capable of reliably delivering 10 Mbps data rates.

2.2.2 WBFH Waveform is Extremely Inefficient

CUBE Reply Comments, page 4:

"[WBFH devices will] achieve high-capacity transmissions while consuming very little power – a critical consideration for mobile devices."

Response

One of the advantages of Frequency Shift Keying is that it is a constant envelope modulation technique. As such, it can be effectively implemented using non-linear transmit power amplifiers. These amplifiers do have an advantage in terms of power added efficiency (PAE) relative to the linear amplifiers used in the latest DSSS systems. This advantage can be as much as 3 to 6 dB. Therefore, for a given level of power consumption by the transmitter output power amplifier, an FHSS device can radiate more energy due to the higher efficiency of non-linear power amps.

However, DSSS systems use DQPSK modulation to transmit high rate data, while WBFH systems will be forced to employ 4FSK modulation. The Eb/No vs BER curves shown in Figure 2.1.1-1 indicate that DQPSK is a far more efficient form of modulation. Based on a BER of 10^{-5}, DQPSK is roughly 15 dB more efficient than 4FSK. Therefore, for the situation described above in which the DSSS transmitter PA is drawing the same amount of power as the non-linear FHSS transmitter PA, the DSSS system will have a net link budget advantage of 9 to 12 dB (again, assuming the non-linear FSK PA is 3 to 6 dB more efficient).

The higher signal level required for reliable demodulation of 4FSK data is one of the more severe drawbacks associated with the claims of the proponents of WBFH. For a given data rate and a given range, WBFH systems will be required to transmit much higher power levels than DSSS systems. This concern is only exacerbated by the fact that WBFH proponents target multimedia applications which include streaming video and CD quality audio. WBFH systems will forced to transmit at very high power levels on an essentially continuous basis to service these applications.

2.3 CUBE Section I: WBFH Deployment

2.3.1 WBFH is Not Scaleable

Cube Reply Comments, page 10

"The primary disadvantage of the 2.4 GHz band is interference from microwave ovens, and from an impending avalanche of new communications devices. FH systems, however, are unique in their abilities to overcome this disadvantage because they provide excellent

interference immunity. Moreover, they are able to achieve high network density on multi-family dwellings, low latency for voice transmission, and inherently lower cost than DS alternatives."

Response:

Interference immunity is a complex issue. As described more fully below, blanket statements concerning the superiority of FHSS systems to interference are overly simplistic. For a more complete discussion of this topic, refer to Section 2.4.7 below. The ability to provide high network density is highly dependent on the receiver bandwidth. Expansion of the receiver passband by a factor of 5 to accommodate the WBFH waveform will seriously undermine the scalability of FHSS systems.

Low latency for voice applications is related to protocol features which enable the use of time domain multiple access (TDMA) medium sharing. Such features can be realized using FHSS, DSSS, or any of a number of other modulation schemes woth appropriate parameters for preamble and frame transmission duration time. This capability is not unique to FHSS systems. The issue of relative cost of FHSS vs DSSS systems in relation to delivery of broadband data rates was discussed in Section 2.1.1.

2.3.2 Bounded Latency is Not Unique to FHSS

CUBE Reply Comments, page 13:

"Furthermore, convergence with telephony is much easier with FH than with high-rate DS because of the superior interference immunity and bounded latency of FH."

Response:

FHSS and DSSS systems combat interference with fundamentally different methods. Blanket claims regarding the superiority of one method over the other necessarily involve over-simplified arguments. As described in Section 2.4.7, DSSS systems have excellent noise suppression characteristics.

Regarding bounded latency, this characteristic depends entirely upon medium sharing mechanisms designed into the Medium Access Controller, and can be implemented using either

DSSS or FHSS physical layers. Implying that DSSS systems are incapable of servicing TDMA applications is incorrect.

2.3.3 WBFH Channel Equalization Claims are Unsupported

CUBE Reply Comments, page 14:

"For robust and reliable performance, most WBFH systems will likely use a simple adaptive equalizer to combat what multipath interference might be encountered in typical home environments."

Response:

The rule changes being contemplated to accommodate WBFH will not be restricted in their application to the home environment. Further, a substantial proportion of homes do, in fact, have significant delay spread [5]. Finally, CUBE's claim that "most WBFH systems will likely use a simple adaptive equalizer" cannot be counted as credible, given the complete absence of supporting technical data.

Channel equalization methods that support high rate data transfer in dynamic channels are fairly complex, even for radios that employ linear front ends. The radios described by the proponents of WBFH rely on non-linear front ends, which strip amplitude information from the received signal. As a result, channel estimates are very difficult to derive. Therefore, CUBE's claims regarding multipath performance should be ignored given the complete lack of supporting data.

2.4 CUBE Section II: WBFH Performance

2.4.1 WBFH Cost Claims are Misleading

CUBE Reply Comments, page 15:

"Similar speed (11 Mbps) DS products based on the IEEE 802.11b specification will need at least $40 in semiconductors per radio and, even at this significantly higher cost, will not provide the high quality cordless telephony support or streaming media quality of service options available in WBFH products."